WATER & SCIENCE AG-VENTURES

FEBRUARY 12, 14 & 15, 2002

PRESENTED BY:

		University of Arizona **Soil, Water and Environmental Science Department**

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* These topics will not be on this year's tour, but are included for reference. Additionally, find out about other experiments you can try by visiting the US Water Conservation Lab web site at: *http://www.uswcl.ars.ag.gov/events/exper/exper.htm*

Welcome

Dear Students and Faculty:

It is our pleasure to welcome you to the Water & Science Ag-Ventures, co-sponsored the U.S. Water Conservation Laboratory, Agricultural Research Service (ARS) of the U.S. Department of Agriculture; the University of Arizona Maricopa Agricultural Center; and the Soil, Water and Environmental Science Department at the University of Arizona. The U.S. Water Conservation Laboratory is one facility in a network of ARS laboratories throughout the nation. Each ARS laboratory specializes in a particular field of study.

On this tour, you will have the opportunity to participate in several of the research programs conducted at the U.S. Water Conservation Lab and gain first-hand experience of agricultural production. We have scientists and engineers studying the impact of global change on agricultural production, investigating new crops, developing applications of remote sensing to agriculture, finding ways to protect ground water, determining more efficient irrigation methods, and designing new ways to get water to the farm. You can find out more about the U.S. Water Conservation Lab by visiting our web page at: *http://www.uswcl.ars.ag.gov/*

You will also have a chance to find out about other agricultural research conduction by the University of Arizona, including aquaculture (raising fish) and have the chance to set out irrigation siphon tubes. You'll also learn the importance soil plays in producing the food we eat and about opportunities to become a student at the University of Arizona.

As you will see, a single problem can be attacked from many directions, employing a wide variety of disciplines. It is this combination of innovative thought and experimentation that makes our work, dare we say it?… fun!

Every year we take this opportunity to show off a little, and we hope, provide some inspiration and encouragement to those of you considering a science or engineering career. We'll even give you some ideas on the agricultural and natural science careers available. We are always looking for good ideas and the minds to implement them.

The following pages provide you with some background on the things you will see during the tour. You will be participating in some of the experiments and trying to figure out the results. It is our hope that you will study this guide and familiarize yourselves with the material. By taking the time to do this, you will be better prepared to understand the information presented. It will also give you a chance to come up with some good questions to make us think (and even squirm a bit).

Thanks for coming,

Ed Barnes and Dave Dierig, U.S. Water Conservation Laboratory
Victor Jimenez, Maricopa County 4-H

SPYING ON PLANTS

Using Remote Sensing Tools for Farm Management

Tom Clarke, Glenn Fitzgerald, and Paul Pinter
U.S. Water Conservation Laboratory

INTRODUCTION

In the future, satellites orbiting hundreds of miles above the earth's surface may provide vital information to farmers, helping them manage their crops more efficiently. Scientists and engineers at the U.S. Water Conservation Laboratory are actively pursuing the background research necessary for this development to be realized. Their goal is to use remote sensing technology to help farmers and ranchers decide when and where to irrigate, fertilize, and apply pest control measures to cultivated lands and pastures.

Visitors will participate in an experiment to develop a watering schedule for potted plants using a thermal imaging system and hand-held infrared thermometer.

What Is "Remote Sensing"?

In its broadest context, remote sensing may be defined as any <u>non-contact</u> means by which an observer can obtain information about a distant object. The eye is a useful analogy for a remote sensing instrument. In humans, it is capable of detecting energy that is reflected by an object in the visible portion of the spectrum ranging from blue to red light. However, compared to other members of the animal kingdom, we have a rather restricted view of the world around us. Foraging insects, for example, can identify flowers using reflected light in wavelengths slightly longer than our eyes can detect, in a part of the spectrum called the near-infrared. Rattlesnakes have a specialized sensory organ just in front of each eye that can actually detect the heat radiating from warm-bodied prey. This energy is referred to as thermal infrared radiation. It, too, is part of the electromagnetic spectrum but is found at wavelengths many times longer than the human eye can detect. Human skin is a rudimentary thermal IR detector. Have you ever stood close to a brick wall after sunset and felt the day's heat radiating from it?

The instruments involved in remote sensing research are most often radiometers which, like a camera's light meter, can measure the amount of light present in particular spectral bandwidths (a spectral bandwidth is simply a range of wavelengths: for example, the spectral bandwidth from 0.45 to 0.50 microns is commonly referred to as the color "blue"). The amount of light reflected in the red (0.65 to 0.70-micron) and near-infrared (0.8 to 0.9-micron) portions of the spectrum can be used to measure accurately the amount of vegetation present in a radiometer's field-of-view. This is useful in monitoring a crop's growth over time and in detecting nutrient problems and damage caused by insects. Instruments sensing thermal infrared radiation (8.0 to 14.0 microns) can actually measure the surface temperature of plant leaves from a distance and in turn, tell us if a plant has enough water around its roots. This is significant. It means we can now use remote sensing instruments not only to measure qualities of a surface, but also to evaluate properties like soil moisture several centimeters below the surface.

Using Leaf Temperature to Detect a Plant's Water Needs

How can the temperature of a plant's leaves tell anybody anything about the amount of water in the soil? Let's use an example that's familiar to most of us in Arizona--the evaporative or swamp cooler. A swamp cooler works by drawing hot, dry Arizona air through a wet pad. The water on the pad evaporates, so that the air coming out of the device is more humid, and also cooler, since the process of changing water from a liquid to a vapor absorbs quite a bit of energy (heat). If you were able to measure the temperature of the evaporative pad itself, you would probably find that it's 10 or more degrees Celsius cooler than the air going into it.

What happens when you turn off the water to the cooler? The water already present on the pad eventually dries up, evaporation ceases, and the mechanism for cooling comes to an end. The pad warms up.

You can think of a plant as a bionic swamp cooler. The leaf surface is peppered with microscopic pores called stomata through which the plant obtains CO_2 from the air for photosynthesis. During the CO_2 exchange, water inside the leaf also evaporates, and the vapor escapes through the stomata. This process absorbs energy just as it does in the evaporative cooler, and it reduces the temperature of the leaf. A well-watered plant can have a leaf temperature many degrees cooler than the surrounding air. It's a good adaptation for agricultural crops to have. Many could not survive the extreme desert heat if it were not for this cooling mechanism.

Where does the water in the leaf come from? It is drawn up from the roots, which in turn absorb it from the surrounding soil. So, when the soil dries out, the roots have nothing to absorb, no water is being delivered to the leaves, and we've just turned off the water to our bionic swamp cooler. What happens to the leaf temperature?

HYPOTHESIS

Measuring the temperature of a plant's leaves is a good way to assess the amount of water present in the soil and its availability to plants.

EXPERIMENTAL PROCEDURES

1. Several potted plants will be watered sequentially, providing plants that have gone one to nine days since their last watering.

2. The percentage of available water used up by each plant will have been determined by weighing the pots.

3. Hand-held thermal radiometers will be used to measure individual plant temperatures.

4. Students will graph the average leaf temperature of each plant versus the days that have elapsed since they were last watered.

RESULTS AND DISCUSSION

What are you findings? What is the connection between leaf temperature and the amount of water in the root zone? Study questions on the following page will help you focus on important conclusions and ways that plant temperature can be used for farm management.

Careers in Agricultural Remote Sensing

Use of optical and thermal remote sensing techniques for agricultural applications is still in the research stage and, as such, career opportunities are mostly found in government research agencies, universities, and large environmental consulting firms. To obtain technical positions in remote sensing, academic course work should emphasize agronomy, soil science, botany, geography and/or hydrology with supplementary course work in mathematics, computer science, optical sciences, physics, and image processing. Research positions in this field usually require a graduate degree at the Master of Science level or higher.

Additional Reading Material

Remote sensing texts:

<u>Manual of Remote Sensing.</u> <u>Volume I. Theory, instruments and techniques.</u> <u>Volume II. Interpretation and applications.</u> 1983. [Second Edition] Robert N. Colwell, Editor-in-Chief. American Society of Photogrammetry. Sheridan Press. 2724 pp.

<u>Remote Sensing: with Special Reference to Agriculture and Forestry.</u> 1970. National Academy of Sciences. Washington, D.C. 424 pp.

<u>Theory and Applications of Optical Remote Sensing.</u> 1989. Ghassem Asrar, Editor. John Wiley and Sons. New York. 734 pp.

Study Questions:

1. Why are the infrared surface temperatures of crops growing in Arizona often several degrees below air temperature?

2. In the demonstration, a thermal scanner was used to measure infrared surface temperatures of plants that had been irrigated at different times. You graphed plant temperature versus the number of days that had elapsed since the plants were last watered. What temperatures indicated that plants had recently been irrigated? What temperatures did the water-stressed plants display?

3. What temperature indicates the plants have used 50% of the moisture in the soil? Do you expect that this temperature might vary with air temperature and humidity? Why?

4. How might a farmer use this technique to schedule irrigations? What are some of the advantages of using infrared thermometry over a calendar method of scheduling irrigations?

5. Suppose you observed unusually warm plant temperatures even though the plants were just irrigated one or two days earlier. What might this be telling you about the soil or plants?

6. Was the thermal scanner more or less sensitive than your eye in determining water stress?

7. Would an infrared scanner be able to measure temperatures accurately in the dark? Would it be as useful for monitoring plant stress at night? Explain your answers.

8. What else might surface temperature data from agricultural fields be useful for?

9. Why doesn't a swamp cooler work very well after the summer monsoons have arrived? Could this same effect impact plant temperatures?

SOILS, SODIUM, AND SCIENCE

Tom Wilson
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INTRODUCTION

Water quality plays a critical role in sustainable agriculture. In fact, salt accumulation in the soil from irrigation water has been recognized as a factor leading to the demise of entire societies, including ancient Mesopotamia. Not all salts are created equal, however. For example, ordinary table salt (sodium chloride, or NaCl) creates a set of conditions for the agriculturalist or land-use manager that differs from those of other salts such as calcium (Ca^{2+}) or magnesium (Mg^{2+}). The interaction between salts and soil can occur on a microscopic scale, but the effects can be obvious, including poor soil drainage and failed crops.

COLLOIDS AND YOU

Colloids are soil particles that are less than 0.002mm in diameter. These particles include clay and organic matter, and are often associated with a negative electric charge due to their molecular composition. Meanwhile, salts possess a positive charge and are often attracted to colloid surfaces.

FLOCCULATION AND DISPERSION

Colloidal particles dispersed in water are called suspensions or sols. Soils may be **flocculated** or coagulated by adding solutions of salts, electrolytes, to them. In soils the colloidal particles, clays and humus, are normally flocculated or precipitated; the particles stick to each other to form large sized aggregations of particles (dirt clods) that are not in suspension and will not move in the soil solution. These aggregates form a well-structured soil has excellent drainage because the aggregations also create pathways between them for water movement.

The salts that contribute to flocculated soils (Ca^{2+} and Mg^{2+}) have a high electric charge density and promote flocculation. However, those that possess a charge density insufficient to flocculate colloids (such as Na^{+}) cause **dispersion**: a condition where soil particles remain apart from each other and do not establish soil structure. These salts are insufficient to neutralize the negative charge of the colloids so they repel each other and become dispersed. The kind and amount of salts determines which action occurs.

Soils with high concentrations of sodium have a tendency to disperse or lose their structure, causing poor water infiltration, soil crusting, restricting root penetration, and impeding seedling emergence. Therefore, the concentration of sodium is an important soil property. The **sodium absorption ration** (SAR) is a measure of the amount of sodium in soils and waters relative to the amount of calcium and magnesium. SAR is gradually replacing an older term, **exchangeable sodium percentage** (ESP), in describing soil and water sodicity. The utility of SAR is based on the fact that divalent cations, such as Ca^{2+} and Mg^{2+} favor aggregation, whereas monovalent cations, such as Na^{+} favor dispersion. Irrigation water with a low SAR (a high content of Ca^{2+} and Mg^{2+} relative to the amount of Na^{+}) will enhance soil flocculation. If the amount of Na^{+} is much higher than the amount of Ca^{2+} and Mg^{2+}, then the Na^{2+} is adsorbed and dominates the soil system causing dispersion. The method used to calculate SAR is shown below.

$$\mathrm{SAR} = \frac{[\mathrm{Na}^{+}]}{\sqrt{\dfrac{[\mathrm{Ca}^{+2}]+[\mathrm{Mg}^{+2}]}{2}}}$$

SODIUM-AFFECTED SOILS: WHAT TO DO?

Dealing with a sodium-rich soil is a tricky business. Flushing the soil with clean water can actually remove the salts that maintain flocculation, leading to a worsened drainage condition if sodium exists in the soil. One common treatment to treat sodium-affected (sodic) soils is to add gypsum ($CaSO_4$ * $2H_2O$). Gypsum can force the sodium away from the colloids and into solution, where it can be removed by leaching with water. Calcium then replaces the sodium in the soil.

EXPERIMENTAL PROCEDURE

This experiment is designed to illustrate the principles of flocculation and dispersion for soils held in suspension in water.

A. Add a predetermined quantity of clay-rich soil to the test tube labeled “F” and to the test tube labeled “D”.
B. Add water to each test tube to the indicated volume.
C. Add a spoonful of sodium chloride to the test tube labeled “D”.
D. Add a spoonful of flocculating agent to the test tube labeled “F”.
E. Cap each test tube tightly and shake them vigorously for 20 seconds.
F. Set each test tube in the test tube rack and observe the results.

QUESTIONS, QUESTIONS

1. Which test tube has the clay particles remaining in suspension the longest?
2. Why do the particles settle more quickly in one test tube than the other?
3. Why do dispersed soils have poor drainage?
4. Where does sodium in soils come from?
5. What can we do to prevent sodium accumulation in soils?

CAREERS IN SOIL SCIENCE.

There are many options for a career in soil science in government and private sectors. Here at the University of Arizona, almost all graduating students majoring in Soil, Water and Environmental Science readily find employment. Some have pursued careers in agronomy, helping to improve agricultural practices around the world. Others work with land management of natural ecosystems. Still others practice environmental law, work in laboratories, or promote environmental education. Our graduates all have one thing in common, however: a deep appreciation of the fragility and complexity of soils, and how important they are in sustaining our civilization.

WATER MEASUREMENT AND CONTROL

Brian Wahlin, Skip Eshelman, John Replogle, and Bert Clemmens
U.S. Water Conservation Laboratory

INTRODUCTION

Of the 60 million acres of irrigated farmland in the United States, nearly two-thirds are sloping fields with water flowing onto the high end of the field. The water then flows across the field or down furrows to the lower end. It soaks into the soil during this passage. Therefore, to ensure proper soaking time to all parts of the field, the flow rate and time of flow must be measured and controlled. If the allotted water is added to the field too quickly, it can pass over the field and be wasted out the lower end before it can soak into the soil. On the other extreme, if it is added too slowly, all of it may soak into the soil at the high end of the field, be wasted to deep drainage, and never reach the low end of the field. With the help of computer models of water flow across fields and down furrows, the best flow rate and flow times can be applied using accurate flow-measuring and control equipment. This allows high crop yields while reducing water waste.

Flow Measurement
Many types of flow measuring devices are available. Most of these devices use laboratory tests to define their flow-depth and flow-rate relationships. A disadvantage is that if the device is bent or altered from the tested configuration, it should be returned to the laboratory or be field rated, both expensive processes.

Broad-crested weirs (Figure 1) are shaped so that computer models can accurately predict the depth-flow rate relations based on measured size information. This means that any changes in size from intended can simply be entered into the computer model, and the new, correct equation for the measured size can be determined.

Canal Control
Most water for irrigation is delivered to fields in some kind of canal system or through pipelines. Because pipelines are usually easy to control compared to canals, our efforts have been to control canal flows for appropriate delivery to fields. Water flows from large delivery canals into smaller canals, or laterals, which in turn deliver water to yet smaller field canals that then dump onto the fields. Regulating structures control the flow in open channels just as valves or faucets control the flow in closed pipelines. Flow from larger to smaller canals and level control in the canals themselves have frequently been performed by “undershot” gates. These gates have the water flowing through an opening at the gate bottom formed by lifting the sliding panel. This arrangement is good for maintaining relatively constant flow downstream from the undershot gate but at the expense of making control of the upstream level difficult. Another gate system is the “overshot” gate (Figure 2). This gate operates with water flowing over the top of it and is suited to maintain canal levels relatively constant at the expense of allowing flow rate variations

to pass downstream. Canal control schemes try to take advantage of these differing behaviors to achieve certain operational advantages.

HYPOTHESIS

Overshot gates can more easily and effectively control water levels in main canals and laterals than undershot gates.

EXPERIMENTAL PROCEDURE

For this experiment, two flowing model canal systems will be used to simulate irrigation delivery canal laterals. One lateral canal is equipped with the common undershot gates. The other is equipped with overshot gates. The students will attempt to reestablish constant canal flow levels in their respective laterals after a change in entry flow rate has been imposed. The relative difficulty and time spent to establish and ensure stability for each system will be noted. Significant differences in performance will establish the hypothesis as true or false.

RESULTS AND DISCUSSION

Which of these gates was easier to use? Can you think of reasons why one gate is more intuitive to use than the other one? Can you think of more advantages or disadvantages for overshot and undershot gates?

A farmer uses two devices to make sure the right amount of water gets to the field. Flow measurement devices are used to determine the rate and the amount of water applied to a field. Flow control devices are used to get the water to the field and to guarantee a constant discharge.

Careers in Hydraulic Engineering

Hydraulic engineers help farmers become more efficient in their water use and help them conserve water. Most career opportunities will be found in government agencies, universities, irrigation districts, and consulting firms. To pursue a career in hydraulic engineering, course work such as hydraulics, mathematics, physics, soil science, and computer science should be stressed. A career at the professional level requires a bachelor's degree or higher.

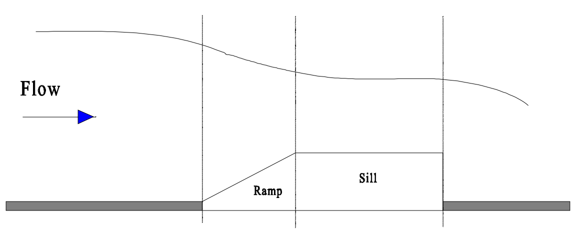

Figure #1:Schematic diagram of a broad-crested weir.

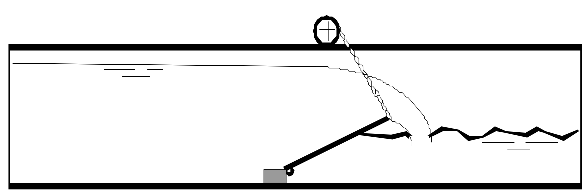

Figure #2:Schematic diagram of an overshot gate.

WILD PLANTS ARE SHOWING UP ON THE FARM LATELY

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U.S. Water Conservation Laboratory

INTRODUCTION

Some plants growing in the wild could be very valuable to American farmers and businessmen. The product from a plant does not have to be a food to be valuable. Industrial crops seem to be a new trend in U.S. farming. These are crops used for some industrial purpose rather than for food. The products are not always obvious, and as a result, many plants have not been "discovered" yet.

Examples of industrial crops would be a fiber used in clothing or paper products, a certain type of oil from the seed of a plant used as lubricants in automobiles, or a fragrance for a perfume. Plants can provide more than one useful product. One plant for example, might have a valuable oil contained in the seed and also a cancer-fighting chemical in its leaves. Also, different plants can produce the same product. Over 2,000 different plant species can produce rubber. Only a few of these, however, are considered important sources. Plant species must be chemically evaluated to find out if they have this potential.

An advantage to domesticating an alternative crop is that it can reduce what we now have to import. The United States imports a great deal of essential industrial raw materials that can be derived from plants that will grow here. We can solve two problems by growing plants that will replace these imports: (1) provide the farmer with another source of cash crops, and (2) improve the country's trade deficit.

Our responsibility here at the U.S. Water Conservation Laboratory, part of the USDA, Agricultural Research Service, is to develop new industrial crops that have potential for commercial production. Unique plants from the wild have to be domesticated before they can be produced in quantity by farmers. Our research program involves plant genetics and breeding, chemistry, agronomy, and irrigation management to achieve this goal.

The new crops we are presently working to develop at this laboratory are

GUAYULE - a source of natural rubber for tires, latex for gloves and various medical products, and resins for marine products. Natural rubber and latex are presently obtained from a tree grown only in tropical areas. Recently, it has been found that many people are allergic to this type of latex. However, they are not allergic to guayule latex.

LESQUERELLA - an oil from the seed that is used in car lubricants, cosmetics such as lipstick, surfactants, and pharmaceuticals. The type of oil in lesquerella is called hydroxy fatty acid. This oil is the same as castor oil that we import. Castor could be grown here but has a toxic seed meal. Lesquerella has some additional uses from castor.

VERNONIA - another oil from the seed that can be used to reduce harmful vapors from paints and varnishes, also for plastics, protective coatings of metals, and various cosmetic products. The type of oil in vernonia is called epoxy fatty acid. Some other oils can be epoxidized to be similar to vernonia oil, but no other plant being produced is naturally epoxidized. Vernonia is a very unusual oil.

All of the above plants contain a product that would replace something we now import.

HYPOTHESIS

Plants and their products can be used to make many things used every day. Some of these are obvious. The paper this is printed on comes from a mixture of wood from different types of trees, usually about 60% hardwood and 40% pine or other softwood. However, another source of paper is from kenaf, a new crop being grown in the U.S. Other products, such as the oil for paints, or for your car, or lipstick, or shampoo can also contain plant oils and products that are less obvious.

EXPERIMENTAL PROCEDURE

After listening to the presentations about new crops and their potential uses and looking at the samples, develop a list of potential new uses/products for some of the plants discussed.

RESULTS AND DISCUSSION

How many different uses and products did you identify?

Careers in New Crops Research

Students can choose from many careers in the area of new crops. Some of the special areas of agriculture that are growing rapidly in the new crop field include oilseeds, nutriceuticals, fiber and energy crops, fruit and vegetable crops, floral crops, and aromatic spices and medicinals. These positions are found in both private industry and public institutions. There are different levels of work, from technician to research scientist. Areas of interest include plant breeding, genetics, ethnobotany, biology/biotechnology, chemistry, botany, physiology, engineering, agronomy, horticulture, pathology, and entomology. The level of education required in the research area varies from undergraduate to post-graduate work, depending on the position. Technicians need at least a B.S. degree in one of the plant sciences, and scientists/engineers need a Ph.D. with some post-doctoral experience.

Additional References

Perspectives on New Crops and New Uses. J. Janick, Ed., ASHS Press, Alexandria, VA. 528 pp. This book is fourth in a series on national symposia on new crops. Visit web sites http://www.hort.purdue.edu/newcrop; http://www.aaic.org; http://www.newuses.org

Where am I??? - GPS to the Rescue

Ed Barnes, Ric Rokey, and Bill Luckett
U.S. Water Conservation Laboratory

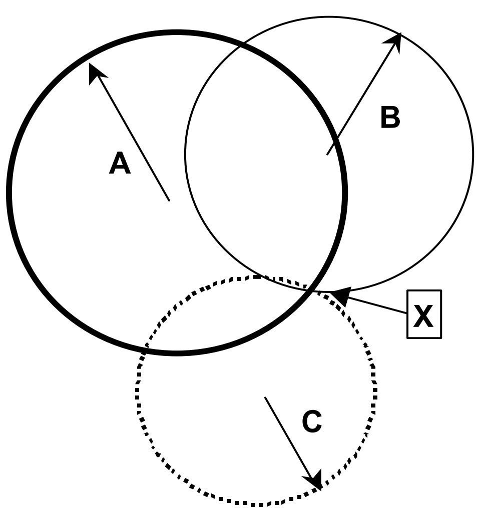
INTRODUCTION

Have you ever been lost while out for a hike or driving in a new town? Wouldn't be nice if you could just look at a computer screen and see a map with a dot on it showing your exact location? Today that is possible because of something called the Global Position System (GPS). This system is composed of 24 satellites orbiting the Earth and a device to receive a signal from these satellites called a GPS receiver. The satellites were originally intended for military applications, but as you'll see at this stop, there are plenty of ways we can all benefit from the system. You'll also see how things you learn in geometry, algebra and geography can all be used to figure out important problems.

How It Works

At any given time, there are from 4 to 12 GPS satellites about 17,700 km (11,000 miles) overhead. Each satellite transmits a signal that contains a digital pattern at the exact same time. To make sure all the satellites transmit together, they use extremely precise atomic clocks (accurate to within nanoseconds - that's 0.000000001 second!). Because the satellites are at different distances from the receiver, the time it takes for the signal to reach the receiver will be slightly different for each satellite. Thus the digital patterns will not match exactly and the receiver can use the difference in the patterns to determine how far away each satellite is. By looking at the patterns, the GPS receiver does not need a very precise clock like the satellite - a good thing, as atomic clocks cost around $50,000.

So now we know how far we are from each satellite, but how does that tell us where we are? This is where all that time you spent in geometry and algebra classes pays off. The answer is easier to understand if we limit the explanation to two-dimensional space. Say you know you are distance A from one satellite, and distances B and C from two others. If we draw circles with radii of A, B, and C centered at the location of the satellite (see figure to the left), the point where all three circles intersect (X) provides our location. In reality, it's a little more complicated - instead of drawing circles you draw spheres - and you need to add a fourth satellite if you want an estimate of you altitude. When working in three dimensions this process is call "trilateration".



In general, the accuracy of your position estimate increases as more satellites are used to perform the calculations. Prior to May 2000, the military purposely introduced error in the satellite signals (called Selective Availability) so even under the best circumstances a civilian could only know their exact location to within 30 meters (100 feet). Altitude estimates are less precise. At present that error is not introduced and most GPS receivers can be accurate to within 4.5 to 9 meters (15 or 30 feet horizontal position) depending on the number of satellites in view. Most of this remaining error is due to random and atmospheric effects; however, additional corrections can be done using a second GPS receiver placed in a known location. The receiver in the fixed location sends a correction to the one that is moving. This method, called differential correction, can allow very accurate GPS measurements with error less than 1-cm (0.4 inches) with some of the best systems.

Coordinate Systems

Altitude, latitude and longitude. Altitude is usually expressed as height above sea level (MAC is about 360 meters {1180 feet} above sea level), although the number some GPS receivers give you is height above a different reference point. Altitude is typically the least accurate measurement; sometimes the error can be more than 75 meters (250 feet). *Latitude* is a measure of how far north or south you are from the equator in degrees (0 degrees is the equator, 90 degree is the north pole). *Longitude* is a measure of you distance in the *east* and *west* direction from the prime meridian at Greenwich, England (0 in Greenwich England to 180 degrees either west or east). Thinking in degrees isn't always easy and it doesn't work well on a flat map, so geographers have come up with different ways to project the globe onto a flat surface. One common projection method used in agriculture and environmental science is called the Universal Transverse Mercator (UTM) projection. The world is divided up into "zones" and then assigned planar (X and Y) coordinates in meters. The advantage of the UTM projection is that the coordinates are given in meters, so if you walk 10 meters (32.8 feet) east, your east coordinate will increase by 10 meters. Another tricky thing about projections is the idea of a *datum*, which defines the origin of the coordinate system. GPS coordinates are based on the World Geodetic System 1984 (WGS-84) datum. If you take coordinates from a GPS and want to find that spot on the map, the map has to be based on the same datum or you have to convert the coordinates to the map's datum.

Latitude and longitude are sometimes expressed in "degrees, minutes and seconds". This can be a little confusing, but the conversion to decimal degrees is pretty easy. For example, if you are at latitude 33 degrees, 15 minutes, 30 seconds North (sometimes written $30^{o}15'30''$ N) and want to express this in decimal degrees:

1. First convert seconds to minutes by dividing by 60
   example: minutes = 30 / 60 = 0.5
2. Next add the result from step 1 to minutes
   example: 15 + 0.5 = 15.5
3. Convert this to a fraction of a degree by dividing the result in step 2 by 60
   example: 15.5 / 60 = 0.25833
4. Now add the result from step 3 to the degrees:
   example: 33 + 0.25833 = 33.25833 degrees

The coordinates for the center of MAC farm are:

Latitude: 33 degrees 04 minutes 21.44190 seconds North = 33.07262275^{o} N

Longitude: 111 degrees 58 minutes, 45.30108 seconds West = 111.9792503 ^{o} W

Or for a UTM projection, MAC is in "Zone 12N" with the coordinates:

3,659,764.23 **m North**, 408,595.719 **m East**

Figure 1 shows an image of the area we are at right now. See if you can find our location - its in the square (sometimes called a "grid") formed between 3659800 and 3659900 m North and 409000 and 409100 m East.

There are lots of other things you can learn about coordinate systems and how GPS works by checking out the references at the end of this report.

HYPOTHESIS

An inexpensive GPS receiver can estimate our elevation above sea level with an accuracy of 30 meters (100 feet) and lead us to within 5 meters (16 feet) of a given location.

EXPERIMENTAL PROCEDURES

You will be divided into three groups and each group will be given a GPS receiver. These receivers are on loan from staff at the Water Conservation Lab so please be very careful with them. Each receiver is a little different, so each group will be given individual instructions on how to use them. Record the following information:

1. Note the elevation reading provided by your GPS: _______________ *circle:* **feet** or **meters**
2. Actual Elevation: 360 meters (1180 feet)
3. Calculate the error: _____________ GPS - actual = ________________
4. Do you accept or reject the first hypothesis?

Next you will be shown how to use the GPS to guide you to a predetermined point (called a "way point"). Most of the GPS receivers will have an arrow that point in the direction you need to walk. **IMPORTANT**: A GPS receiver is not a compass and it can only point you in the right direction when you are moving. Therefore start walking before you try to follow the arrow.

When the GPS says you have reached your location (special instructions will be given on how to determine this for each receiver), look for the closest flag. Check the number on the flag and ask if you have found the right flag. If not, find out the flag you should have reached. Have one person stay in the position the GPS led you to and another member of the group count the number of paces to the flag. Record the following:

1. Number of paces to the flag: ___________
2. Assume one pace is approximately 3 feet (1 meter) and calculate the distance to the flag: ________ Paces * 1 = ________ m and ________ Paces * 3 = _________ feet
3. Do you accept or reject the second hypothesis?

Applications of GPS Data

GPS receivers are being integrated into products some of us use on a daily basis. Examples include:

- Some companies are adding GPS to cell phones so that rescue crews can locate people making 911 calls.
- Rental car companies are adding the option to have a GPS receiver tied into a computer so the car can tell the driver where to turn to get to their destination.
- Navigation when hiking or boating.
- Very precise GPS receivers are starting to replace more traditional types of surveying equipment (transits and total stations).
- In agriculture, GPS receivers are an important component of what is often called "precision" or "site-specific" farming. GPS allows farmers to precisely map what crops need in each area. A GPS receiver then "tells" the equipment applying fertilizer or pesticides how much to apply to each part of the field. This saves the farmer money by only applying what the crops needs and reduces the chances that any agricultural chemicals will soak into the ground water and not be washed into streams and rivers.
- Many areas of the environmental sciences use GPS technology. Wildlife biologist use GPS determined locations to map sightings of various animals, while those studying global change use it to determine slight changes in glaciers.

Try to think of other applications you could add to the list.

References:

USDA Forest Service web site at: *http://www.fs.fed.us/database/gps/gpslinks.htm*

GPS MADE EASY by L. Letham, The Mountaineers Publishing, 1995

USDA, ARS, US Water Conservation Lab Remote Sensing web link at: *http://www.uswcl.ars.ag.gov/EPD/remsen/rsmiss.htm* for information on precision farming.

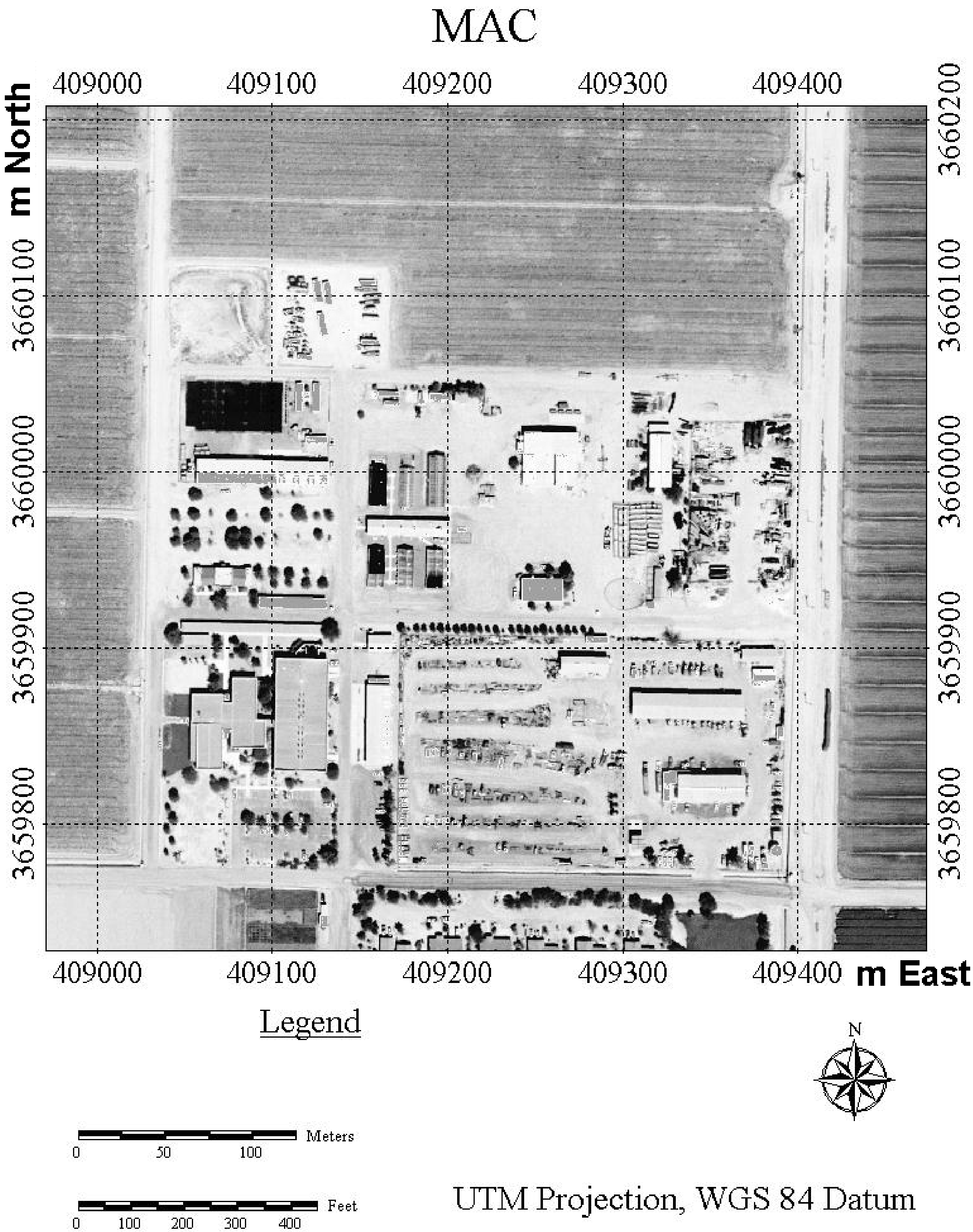


Figure 1. UTM grid overlaid on an image of the office and shop complex at MAC.

CAREERS IN AGRICULTURE AND THE NATURAL SCIENCES*

Ed Barnes
U.S. Water Conservation Lab

INTRODUCTION

For many people, the term "agriculture" brings to mind a farmer with an old straw hat and maybe a cow and a barn. In reality, agriculture involves the combination of a variety of scientific and engineering disciplines working together to solve complex problems. As the world's population continues to increase and the area of land used for agricultural production decreases, improving our agricultural productivity will remain a priority. Another aspect to agricultural production is the need to protect natural resources so that croplands remain productive and the environment is protected. During this tour you have met or will meet physical scientists, geneticists, and engineers and learn about their careers. Here we will take a more general look at the potential careers in agriculture and environmental sciences.

Career Overview

Crop Science
Crop scientists study every aspect of crop growth and development. It can involve studying plant genetics, breeding new and improved crop varieties, evaluating cell biology and molecular genetics, or determining better ways to manage the way a crop is grown in the field. Some crop scientists specialize in controlling problems that reduce crop productivity such as weeds, disease, or insects. A good background in high school biology and chemistry will help prepare you if you decide to study this area when in college.

Soil Science
Soil scientists study every aspect of soils, from chemical and physical properties to how soils can be protected from erosion and chemical contamination. Soil scientists model water flow through the soil to determine how chemicals and nutrients move. They also classify soils so others can determine what is the best use for a particular area of land. Chemistry, mathematics, and biology are important areas to study.

Agricultural and Civil Engineering
Agricultural and civil engineers work on a variety of problems related to agriculture. Agricultural engineers design agricultural machinery, everything from tractors to food processing equipment. Both agricultural and civil engineers design irrigation equipment and canals. To pursue an engineering career you need extensive training in mathematics, physics, and the basic sciences.

Where Can I Work?

Research Institutions
Research positions are available for all the agricultural disciplines with both governmental and private agencies. Universities all across the world need scientists for teaching and research. Additionally, there are many careers as laboratory and field technicians to conduct analysis and collect field data. Some universities also have agricultural extension programs, where people who have specific skills work directly with agricultural producers and the public to transfer the results from research projects to solve everyday problems.

Private Industry
Seed and agricultural companies conduct research to determine new ways to improve their products, so these companies have their own research staffs. There are also consulting positions available, in which the consult helps the farmer decide the best way to control weeds, disease, and insects on the farm. Countless other opportunities exist in the food processing industry for engineers, chemists, and biologists to improve existing processing technologies and insure that our food supply remains safe.

How do I get there?

For any career in agriculture and natural sciences you will want to take as many high school courses as possible in biology, chemistry, and mathematics (and of course agricultural sciences if such a program is available at your school). For soil science and engineering, physics will also be important. Many schools have programs such as 4H and Future Farmers of America (FFA) that can provide valuable exposure to agricultural experiences.

For some laboratory and field technician positions, it may be possible to find a job with only a high school education, but for most positions a minimum of a bachelor's degree is needed. If you already know you want to be involved in research, graduate studies will be required.

THE POOR MAN'S BIOSPHERE— RESEARCH AND DEVELOPMENT PROGRAM*

Sherwood Idso
U.S. Water Conservation Laboratory

INTRODUCTION

Carbon dioxide (CO_2) is a colorless, odorless gas that is released to the atmosphere in prodigious quantities by the burning of fossil fuels such as coal, gas, and oil. Since the beginning of the Industrial Revolution, its concentration in the air has risen from about 280 parts per million (ppm) to more than 360 ppm today. Many people fear that this rise in the atmospheric CO_2 content will lead to a catastrophic warming of the globe by intensifying earth's natural "greenhouse effect." Counterbalancing this potential detriment, however, are a number of benefits of atmospheric CO_2 enrichment for plant growth and development, upon which nearly all life depends for its sustenance. As a consequence, there is considerable uncertainty over what, if anything, should be done about industrial activities that release CO_2 to the air. At the U.S. Water Conservation Laboratory, we are working to reduce this uncertainty by learning all we can about the effects of higher-than-normal atmospheric CO_2 concentrations on plant productivity.

PROBLEM

In order to act in the best interests of the biosphere in the face of the rising CO_2 content of earth's atmosphere, we need to determine the effects of atmospheric CO_2 enrichment on the growth of as many different plants as possible, both singly and in combination with competing plants and animals. Also needed is a knowledge of how the ongoing rise in the air's CO_2 content may interact with such things as global warming, drought, and soil, water, and air pollution, so we can determine if the deleterious effects of these latter phenomena will be ameliorated or exacerbated by the rise in atmospheric CO_2. Consequently, in an attempt to expand our research capabilities in this important area of science, and to interest more young people in pursuing careers therein, this project has as its goal the development of a number of simple and inexpensive techniques that will enable almost anyone to conduct significant research on a variety of questions related to the effects of atmospheric CO_2 enrichment on earth's biosphere.

APPROACH

A set of guidelines was developed for using inexpensive and readily available materials to construct simple experimental growth chambers – "Poor Man's Biospheres" – wherein CO_2 enrichment and depletion studies of both aquatic and terrestrial plants may be conducted (Idso, 1997). These enclosures consist of small aquariums (or 2- or 3-liter soda pop bottles) covered by thin sheets of clear polyethylene taped to their upper edges to isolate their internal airspaces from the room or outside air. The CO_2 contents of these airspaces may be enriched by the oxidation of organic matter found in common commercial potting soils, or by CO_2 exhaled by the experimenter. When CO_2 depletion is desired, the growth of the experimental plants can be used to lower the biospheres' internal CO_2 concentrations. In addition, simple procedures for measuring biospheric airspace CO_2 concentration have been developed that utilize colorimetric CO_2 test kits that can be obtained in tropical fish stores throughout the world or ordered over the internet (Idso, 1997).

TECHNOLOGY TRANSFER

The Poor Man's Biosphere approach to atmospheric CO_2 enrichment and depletion experimentation has been tested in a number of different learning situations: a fifth-grade class at the Salt River Elementary School of the Salt River Pima-Maricopa Indian Community, five eighth-grade biology classes at McKemy Middle School in Tempe, Arizona, and two honors biology classes at Tempe High School. It has also been used by units of the Boy Scouts of America and, as part of its environmental science education activities, by the Center for the Study of Carbon Dioxide and Global Change, which has used the technique in a number of experiments that it describes on its website (www.co2science.org), where complete descriptions of these studies are archived for science teachers throughout the world to access and utilize in their classrooms.

Reference

Idso, S.B. 1997. The poor man's biosphere, including simple techniques for conducting CO_2 enrichment and depletion experiments on aquatic and terrestrial plants. *Environmental and Experimental Botany* **38**: 15-38.

Careers in CO_2 Research

Plant physiologists, soil scientists, microbiologists, and entomologists are needed to conduct research into the many biological processes that are affected by atmospheric CO_2 enrichment. Atmospheric physicists, climatologists, and hydrologists are likewise needed to study the effects of CO_2 on global weather patterns and long-term climate change. Both fields of research also depend on computer specialists and mathematicians to develop models of these phenomena. Work is conducted at all levels of government, at universities, and in the private sector, such as at Biosphere II near Tucson.

Additional Reading Material

Books:

> *Carbon Dioxide Enrichment of Greenhouse Crops*. 1986. H.Z. Enoch and B.A. Kimball, editors. CRC Press, Boca Raton, FL.

Carbon Dioxide and Global Change: Earth in Transition. 1989. S. B. Idso. IBR Press, Tempe, AZ.

Impact of Carbon Dioxide, Trace Gases, and Climate Change on Global Agriculture. 1990. B.A. Kimball, editor. American Society of Agronomy, Madison, WI.

Journals:

Agricultural and Forest Meteorology
Plant, Cell and Environment
Environmental and Experimental Botany
Plant Physiology

The Poor Man's Biosphere – Level 1 (Most Simple) Instructions

The Poor Man's Biosphere is a simple growth chamber that can be used to conduct experiments on the effects of increases or decreases in the carbon dioxide (CO_2) content of the air on plants. It was developed by Dr. Sherwood B. Idso of the U.S. Water Conservation Laboratory in Phoenix, Arizona, and is described in detail on the website of *The Center for the Study of Carbon Dioxide and Global Change*, which can be accessed on the Internet at www.co2science.org.

In their most simple configuration, Poor Man's Biosphere units may be constructed from pairs of empty 3-liter soda pop bottles that have had their tops removed (by scissors) above the level where the bottles begin to narrow towards their openings. After cleaning such topped-off bottles and removing the labels glued to their outside surfaces, one of the bottles is filled to within an inch or so of its top with clean aquarium gravel, after which it is filled to just above this level with water. A single leaf is then removed from a Golden Pothos or Devil's Ivy plant by severing the vine to which it is attached at points about half an inch on either side of where the leaf joins the vine. This leaf-vine junction is then carefully pushed (while protected from breaking by holding it between one's fingers) one to two inches below the surface of the gravel. If space permits, a second and possibly third leaf may be added in like manner.

At this point, two pencils are laid across the top of the bottle in such a way as to enable one to place the other topped-off bottle above it in an inverted position. Then, while someone holds this bottle securely in place directly above the bottom bottle, another person uses transparent tape to link the two bottles together, carefully sealing them to create an air-tight unit.

When several such Poor Man Biosphere units are ready, one is left totally sealed, one has a couple of small holes poked in the tape that links the two bottles together, and one has two or three larger holes cut in the tape that links them. The air within the unit with the large (pencil-diameter-size) holes will serve as the high-CO_2 biosphere, as its air will be continually mixing with the air of the room in which it is located; and that room-air will normally be of relatively high CO_2 content, if doors and windows are closed and two or more people are in the home, as exhaled breath is high in carbon dioxide content.

The unit with no holes in it will serve as the low-CO_2 unit, as its air will be depleted of CO_2 when the leaves within it photosynthesize and remove carbon dioxide from the entrapped air, which cannot be replenished because this unit is isolated from the room-air. Last of all, the unit with the small holes in its transparent tape will serve as an intermediate-CO_2 unit, as it will be able to replenish some of the CO_2 removed by the leaves within it, but the process will be slower because of its fewer and/or smaller holes. Hence, its CO_2 concentration will be less than that of the unit with the larger holes in it.

When all is thus ready, the Poor Man's Biospheres are placed near a window to get plenty of light. Alternatively, fluorescent aquarium lights may be set up to illuminate the units from the side, preferably for 24 hours a day. Then, let the experiment begin!

STUDENT NOTES